N65- 88663

BLAST-WAVE CORRELATION OF PRESSURES ON BLUNT-

NOSED CYLINDERS IN PERFECT- AND REAL-GAS

FLOWS AT HYPERSONIC SPEEDS

By Donald M. Kuehn[1]

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, Calif.

ABSTRACT

12662

It is shown that the blast-wave parameter which includes a function of the isentropic exponent, γ, offers the possibility of correlating blunt-nosed cylinder pressures obtained by theoretical solutions and experiment for both perfect and real gases. The result of the correlation is a single equation, in blast-wave form, which should approximate the pressures on blunted cylinders in both real and perfect gases for a wide range of nose drag and Mach number.

[1]Research Scientist

BLAST-WAVE CORRELATION OF PRESSURES ON BLUNT-

NOSED CYLINDERS IN PERFECT- AND REAL-GAS

FLOWS AT HYPERSONIC SPEEDS

By Donald M. Kuehn

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, Calif.

The blast-wave theory has been used in many investigations to correlate the surface pressures for blunted, stream-alined cylinders. The parameter $(x/d)/M_\infty^2 C_D^{1/2}$ has been used for both perfect and real gases (e.g., (1 and 2)).[2] Pressures on cylinders with different nose-drag coefficients, C_D, and free-stream Mach numbers, M_∞, obtained by the method of characteristics are correlated in (1) for each of two perfect gases. The parameter worked very well for constant isentropic exponent, γ, but is inadequate for correlating pressures for various values of γ.

The generalized first-order blast-wave theory for axisymmetric flow (2 and 3) contains a parameter for the effects of the isentropic exponent in addition to the effects of nose drag and Mach number. This parameter has not been exploited in the correlation of cylinder pressures. The correlating parameter is immediately evident from the following equation (2) for the ratio of surface pressure to free-stream pressure:

$$\frac{p}{p_\infty} = f_1(\gamma) \frac{M_\infty^2 C_D^{1/2}}{x/d} \qquad [1]$$

where

$$f_1(\gamma) = \frac{1}{8} \sqrt{\frac{\gamma}{J_0}} \; g(_0^0)$$

---

[2]Numbers in parentheses indicate references at end of paper.

The blast-wave constants J_0 and $g(\overset{O}{O})$ are discussed in (2) and (3).

Values of the γ function are shown in table I.

The perfect-gas characteristics solutions of Van Hise were correlated in (1) by using the blast-wave parameter which does not include the effects of γ. The following equations resulted:

$$\frac{p}{p_\infty} = 0.060 \frac{M_\infty^2 C_D^{1/2}}{x/d} + 0.55 \qquad (\gamma = 1.40) \qquad [2]$$

$$\frac{p}{p_\infty} = 0.075 \frac{M_\infty^2 C_D^{1/2}}{x/d} + 0.55 \qquad (\gamma = 1.67) \qquad [3]$$

These equations reduce to the following single equation when the γ function is included:

$$\frac{p}{p_\infty} = 0.89 \frac{M_\infty^2 C_D^{1/2} f_1(\gamma)}{x/d} + 0.55 \qquad [4]$$

The parameter with the γ function thus correlates the characteristics solutions for these two perfect-gas cases.

The application of the blast-wave parameter which includes the γ function to real-air flows presents a problem because of the variation of γ within the flow fields about blunt bodies. The question thus arises whether a single value of γ can be used to characterize a particular flow field. Bradford Wick of the NASA Ames Research Center has suggested that the value of γ in the stagnation region should be used, since the blast-wave analogy describes the flow in terms of a blast which originates at the nose of a blunt body. This hypothesis can be checked with my unpublished experimental pressure distributions measured in air at a Mach number of 14.4 for three blunt cylinders. The total temperature, 3600° R, and the total pressure, 1000 psia, of the free stream would produce in the

stagnation region of the model a value of γ of about 1.2 for equilibruim

flow and 1.4 for frozen flow. Comparison of theoretical and experimental

pressure distributions and shock stand-off distances indicates that the

former value of γ should apply for the flat-faced cylinder and the latter for

the conical nose. For the hemispherical nose an intermediate value of γ

should apply. The data are shown in Fig. 1 as a function of the blast-

wave parameter based on free-stream Mach number and nose drag computed by

modified Newtonian impact theory. The pressure distributions do not

correlate. It should be emphasized that free-stream conditions were iden-

tical for the three models. The variation in stagnation γ shown in

Fig. 1 is the result of a variation in the extent of vibrational relax-

ation. The experimental pressure distributions correlated with the blast-

wave parameter generalized to include the γ function are shown in Fig. 2,

along with the curve representing the correlated characteristics solutions

given by Eq. [4]. The experimental data correlate very well; further, the

correlated experimental data are in very good agreement with the correlated

characteristics solutions.

Although the foregoing correlation is by no means definitive, it does

indicate the possibility of using a single correlation equation for surface

pressures on blunted cylinders in perfect and real gases for a wide range

of nose drag and Mach number. Further evaluation of this type of correlation

is necessary, in particular, for real-gas flows for which stagnation values

of γ are used. In this regard, it is interesting to note that for the

present tests the local γ for equilibrium expansion around the nose of

the flat-faced cylinder varies rapidly from about 1.2 to 1.35 because the

total enthalpy was in the region where γ changes very rapidly with

enthalpy. In contrast, γ changes much more slowly with enthalpy at the high total enthalpies associated with entry flight conditions. For such flight conditions, the choice of γ will, of course, be less questionable.

REFERENCES

1. Van Hise, Vernon: Analytic Study of Induced Pressure on Long Bodies of Revolution with Varying Nose Bluntness at Hypersonic Speeds. NASA TR R-78 (1960).

2. Lukasiewicz, J.: Hypersonic Flow-Blast Analogy. AEDC TR - 61-4 (1961).

3. Sakurai, Akira: On the Propagation and Structure of the Blast Wave, I. Jour. Phys. Soc. of Japan, vol. 8, no. 5, Sept.-Oct. (1953).

TABLE I.- γ FUNCTION DESCRIBED BY BLAST-WAVE THEORY

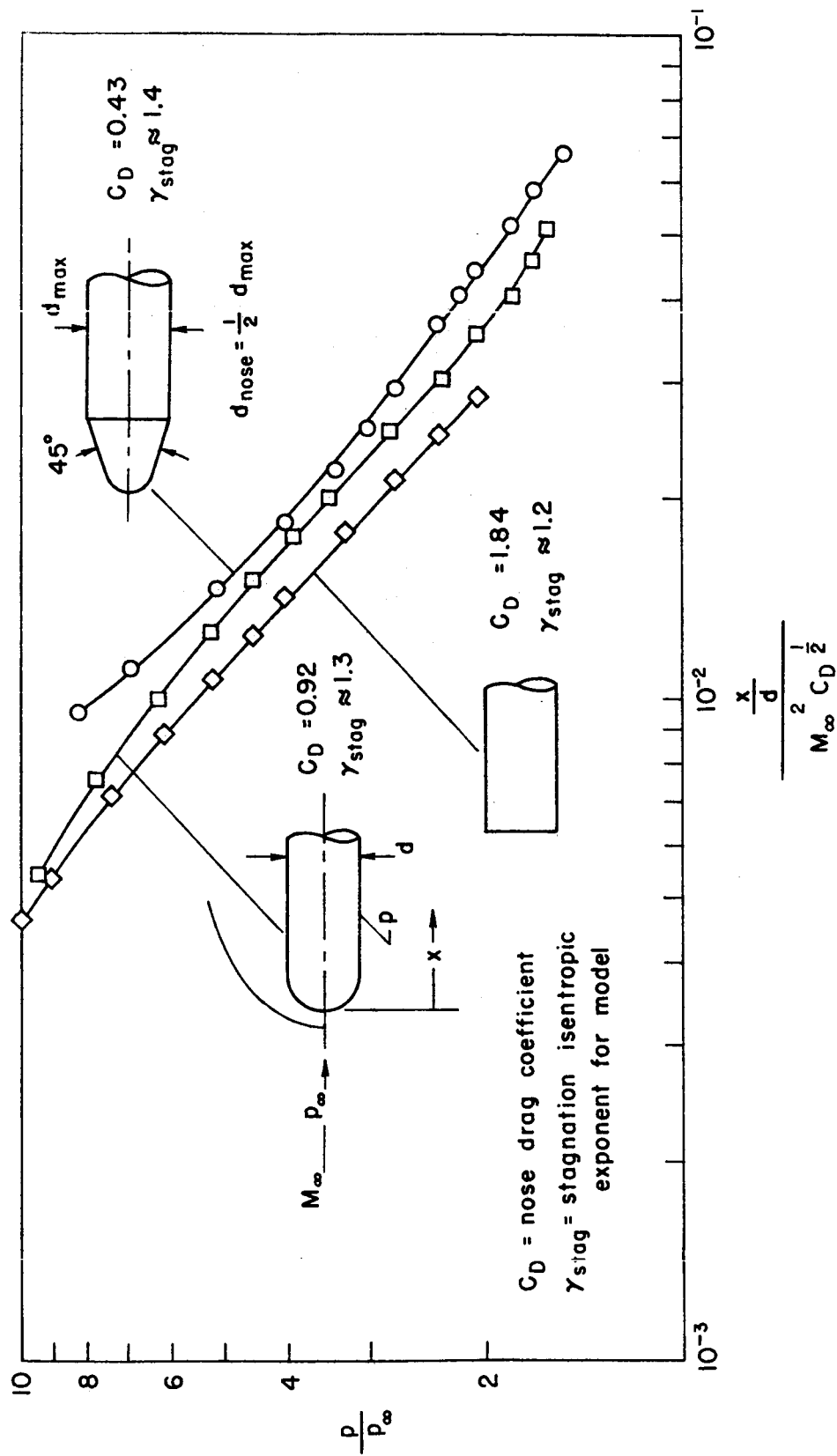| γ	$f_1(\gamma)$
1.15	0.046
1.2	.052
1.3	.061
1.4	.067
1.67	.084

FIGURE TITLES

Fig. 1. Correlation using blast-wave parameter without γ function; experimental data from tests in air at $M = 14.4$.

Fig. 2. Correlation using blast-wave parameter with γ function; experimental data from tests in air at $M = 14.4$.

Fig. 1. Correlation using blast-wave parameter without γ function; experimental data from tests in air at $M = 14.4$.
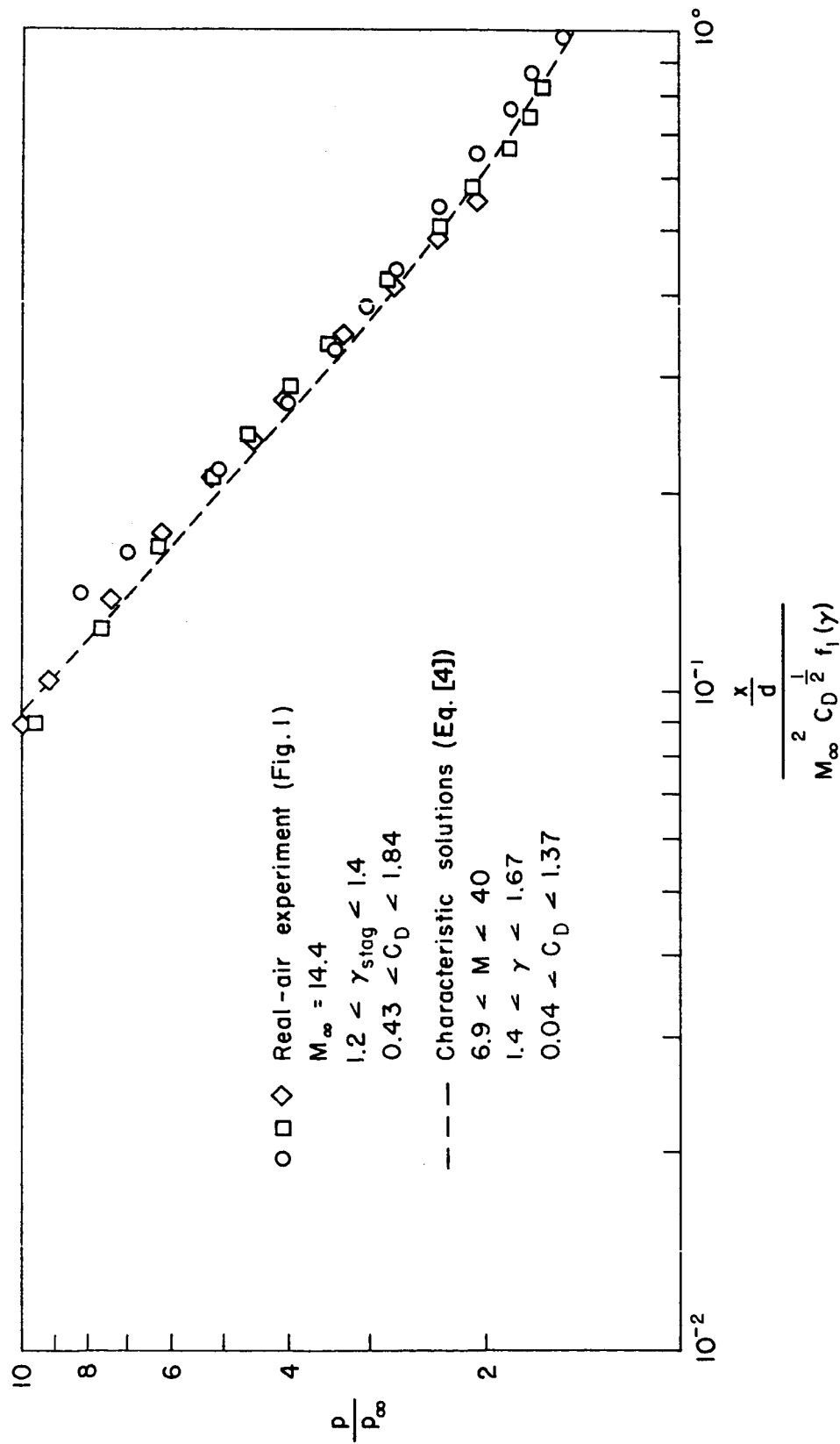
Fig. 2. Correlation using blast-wave parameter with γ function; experimental data from tests in air at $M = 14.4$.